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(71) Applicant: SUMITOMO ELECTRIC INDUSTRIES LIMITED
No. 15, Kitahama 5-chome Higashi-ku
Osaka-shi Osaka 541(JP)

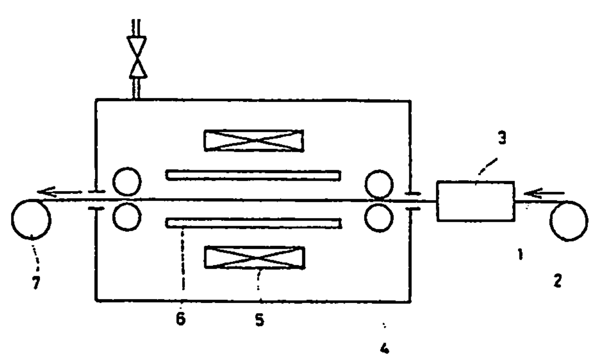
(72) Inventor: Sawada, Kazu Osaka Works
Sumitomo Electric Ind., Ltd. 1-3 Shimaya 1-chome
Konohana-ku Osaka(JP)
Inventor: Nishio, Masanobu Osaka Works
Sumitomo Electric Ind., Ltd. 1-3 Shimaya 1-chome
Konohana-ku Osaka(JP)
Inventor: Nakai, Yoshihiro Osaka Works
Sumitomo Electric Ind., Ltd. 1-3 Shimaya 1-chome
Konohana-ku Osaka(JP)

(74) Representative: Patentanwälte Kirschner & Grosse
Herzog-Wilhelm-Strasse 17
D-8000 München 2(DE)

(54) Conductor and method of producing the same.

(57) A conductor has a core wire whose surface is coated with the same kind of material as the core wire material. A copper wire (1) which forms the core wire has its surface cleaned by a preparatory processing mechanism (3) and then it is fed to a continuous sputtering unit (4). The continuous sputtering mechanism (4) coats the surface of the core wire (1) with copper by coaxial magnetron sputtering method. Thereafter, this wire is drawn by cold working into a thin wire of predetermined size.

FIG.1



EP 0 241 721 A1

Conductor and Method of Producing the Same

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a conductor which is required to be small in diameter and high in quality, such as a copper wire used as a magnet wire, a conductor used in acoustic and image-forming appliances such as stereos and VTRs, and a bonding wire used for connecting semiconductor elements such as integrated circuits and transistors, and it also relates to a method of producing the same.

Description of the Prior Art

Conventionally, in producing thin metal wires, first an ingot is prepared. The ingot is then subjected to multistage hot and cold working a number of times until a thin wire of desired size is obtained.

As a variation thereof, there is a dip forming process as described, for example, on pages 980-987 of Report No. 12, Vol., 21 (1982) from the Japan Institute of Metals. In this process, a core wire is passed at high speed through a crucible containing molten copper, whereby said core wire is thickened as the molten copper sticking thereto solidifies. Thereafter, the core material is rolled to produce a roughly drawn wire.

The conventional methods described above were each developed as suitable methods for mass production (for example, several tons/hour to tens of tons/hour). Thus, they cannot always be said to be suitable methods, from the standpoint of quality, quality control and processability, for producing wires such as conductors used for modern electronics which requires high purity, high quality and severe thinning.

That is, when metal is melted in large amounts, it is impossible to prevent contamination of foreign matter. Further, hot working often causes foreign matter to enter in the vicinity of the metal surface. In the field of very thin wires, wire breakage forms a major factor which impedes productivity. It has been found that most of the wire breaks are caused by foreign matter such as ceramics and iron powders contaminating into the metal during melting and casting or working. Further, multistage wire drawing process makes complicated the control of lubricants, dies, and wire drawing machines.

For conductors used for wiring acoustic and image-forming appliances such as stereos and VTRs, it is considered desirable that conductors contain a miniumum of dissimilar elements including such components as oxygen. However, it is difficult to maintain the entire conductor in the state of high purity copper. The reason is that if, for example, an ingot of high purity copper is remelted or cast, dissimilar elements or foreign matter often contaminates into the metal during processing, thus making it impossible to maintain the high purity. After all, when conventional conductors for acoustic and image-forming appliances are used, it has been impossible to obtain sounds or images of good quality.

It is required that bonding wires for connecting semiconductor elements be small in diameter and high in quality and reliable. Conventionally, as for this type of bonding wires, thin wires of gold, aluminum or copper have been practically used or investigated for practical use. In the case of a thin wire of gold, its connecting property is good, but there is a problem of high cost. In recent years, to reduce cost by avoiding the use of noble metals, bonding wires of aluminium, aluminum alloy, copper or copper alloy have been given attention, being about to be put into practical use. In the case of a bonding wire to be used for connection, contamination of foreign matter should be avoided to maintain the good connecting property. That is, it is considered desirable to use high purity metal in making bonding wires.

However, high purity metal itself is of high cost. Further, its drawing property is poor because of its lack of strength. For example, in the case of a bonding wire of high purity aluminum, because of its low recrystallization temperature, it is recrystallized by the heat of friction produced during drawing. Further, if an ingot for bonding wires made of high purity metal is remelted and cast, there is the danger of foreign matter contaminating into the metal during processing, thus making it impossible to maintain the high purity.

SUMMARY OF THE INVENTION

An object of this invention is to provide a production method capable of obtaining a thin metal wire of high purity and high quality while preventing contamination of foreign matter during production.

Another object of the invention is to provide a bonding wire for connecting semiconductor elements, which is of low cost and superior in drawing property and capable of maintaining its good connecting property, and to provide a method of producing the same.

A further object of the invention is to provide a conductor for acoustic and image-forming appliances, which is capable of obtaining sounds and images of good quality, and to provide a method of producing the same.

A conductor obtained by the invention is characterized in that the surface of a core wire of electrically conductive material is coated with same kind of material wire as that of the core wire. The method of producing the conductor according to the invention is characterized in that the surface of a metal core wire is coated with the same kind of metal as the metal core wire by vapor phase method. In a preferred embodiment, after the surface of the core wire is coated with the same kind of material by vapor phase method, the core wire is processed by plastic working unit it becomes a thin wire of predetermined size.

The coating by vapor phase method, as compared with that obtained by other coating methods, make it easy to attain high quality and cleanliness. Therefore, if a wire whose surface have been coated with a clean metal having no foreign matter is drawn by plastic working until it becomes a thin wire of predetermined size, a thin metal wire of high purity and high quality can be obtained with less occurrence of wire breakage.

Coating by vapor phase method and plastic working may be alternately performed a number of times. More particularly, the surface of core in the form of a portion or the whole of the thin metal wire of high purity and high quality obtained by the method described above is coated again with the same kind of metal by vapor phase method. Thereafter, this wire is drawn by plastic working. If this process is repeated once or a number of times, a very thin wire of high purity and high quality can be obtained. In this case, contamination of foreign matter rarely occurs and so does wire breakage.

According to the method of the invention, a metal core wire of particularly small diameter is prepared and a metal is deposited on its surface by vapor phase method and then the wire is subjected to plastic working. Therefore, the number of processes by plastic working can be reduced. For this reason, if the invention is used for production of thin wires of less than 30 µm, which should be called very thin wires, process control can be facilitated because of a reduced number of processes involved. Further, processability is good with no excessive force involved in wire drawing, so that efficiency of production is high. Further, the coating metal can be easily made pure to a great degree.

The term "metal" used in this specification includes an alloy, and the term "same kind" includes not only a combination of the same metal but also such a combination as aluminum and an aluminum alloy. Thus, in the method of the invention, the metal which forms the surface of the metal core wire is the same in main components as the coating metal. With the arrangement thus made, the wire obtained is electrochemically stable and the danger of corrosion on the end surfaces can be reduced. Further, the adhesion between the core and the deposited coating material is improved.

As for coating by vapor phase method, physical vapor deposition, such as a sputtering, or chemical vapor deposition, such as plasma CVD method, can be used. If coating is effected by sputtering, a wide variety of materials can be deposited on the core wire with high adhesive strength. Coating by chemical vapor deposition uses a gas which can be easily refined, so that deposition with high purity and high quality is possible.

As for plastic working subsequent to metal coating by vapor phase method, industrially, wire drawing using a drawing die in the cold is convenient. The use of a drawing die enables plastic working to be performed while enhancing the adhesion between the core and the deposited coating material. In this case, plastic working in one process is performed so that preferably the percentage reduction in the cross-sectional area is within the range of 15-90 %. Plastic working with a percentage reduction of less than 15 % would decrease efficiency of production. On the other hand, plastic working with a percentage reduction of more than 90 % would impair the softness and elongation property of the resulting wire. Further, it is sometimes difficult to perform plastic working with a percentage reduction of more than 90 % for each deposition.

The invention, which achieves the merits described above, is effectively employed for the production of bonding wires for connecting semiconductor elements, conductors for wiring image-forming and acoustic appliances, and magnet wires of copper or aluminum.

Preferably, the conductor for acoustic and image-forming appliances is in the form of a copper wire of 99.99 % or above purity whose surface has been coated with copper of 99.999 % or above purity. The method of production of conductors for

acoustic and image-forming appliances is characterized in that the surface of a copper wire of 99.99 % or above is coated with copper of 99.999 % or above by vapor phase method.

High frequency signal currents in acoustic and image-forming appliances flow in the vicinity of the surface of a conductor because of the skin effect. According to the preferred embodiment described above, the core is made of copper of 99.99 % or above purity, while the surface area through which high frequency current flows is made of high purity copper of 99.999 % or above. Therefore, high frequency current flows under a low AC resistance, without the possibility of a phase difference being caused by the effects of impurity elements. Thus, the use of a conductor for acoustic and image-forming appliances according to the invention makes it possible to obtain sounds and images of good quality.

Coating with copper of 99.999 % or above purity is realized by vapor phase method, dip plating and wire drawing. On the other hand, according to the method of the invention, copper of 99.999 % or above purity is used for coating by vapor phase method. In the case of coating by vapor phase method, as compared with other coating methods, control of high purity and cleanliness is easy. Therefore, the surface of the core can be easily coated with copper or high purity and high quality containing no foreign matter. As for coating by vapor phase method, physical deposition, such as sputtering, or chemical deposition, such as plasma CVD method, can be employed.

Subsequently to coating with copper of high purity by vapor phase method, cold working is performed so that the percentage reduction in cross-sectional area is preferably within the range of 20-90 %. This cold working ensures that sounds and images obtained are of high quality. In the case of a percentage reduction of less than 20 %, improvement in sounds and images would be insufficient. Such improvement will be substantially saturated at a percentage reduction of about 90 %. Thus, with a percentage reduction of more than 90 %, satisfactory improvement could not be expected; rather, there would be the danger of flexibility being impaired.

The bonding wire for wiring semiconductor elements obtained by the invention is preferably in the form of a thin metal wire of copper, aluminum or gold whose surface has been coated with the same kind of metal of higher purity. Therefore, this bonding wire will exhibit a good connecting property. As compared with a bonding wire made entirely of high purity metal, the bonding wire of the invention has its surface alone of high purity metal, so that it is of low cost and superior in drawing property. Thus, the inner metal of relatively low purity contributes to lowering cost and increasing strength.

The terms "copper," "aluminum," and "gold" include their respective alloys, and the term "same kind," as described above, includes not only combination of the same metal but also a combination as aluminum alloy and aluminum.

The coating metal of relatively high purity contributes to improving the connecting property of the bonding wire. In this connection, to ensure a good connecting property, the coating metal is preferably of 99.99 % or above purity. Coating with a metal of relatively high purity is performed by vapor phase method, dip plating or wire drawing, but coating by vapor phase method is particularly preferable. As for coating by vapor phase method, physical deposition, such as sputtering, or chemical deposition, such as plasma CVD method, can be employed.

The method of producing bonding wires for wiring semiconductor elements according to the invention is characterized in that the surface of a thin metal wire of copper, aluminum or gold is coated with the same kind of metal of higher purity than said thin metal wire by vapor phase method. Coating by vapor phase method and subsequent wire drawing may be alternately performed a plurality of time. In this case, contamination of foreign matter rarely occurs and so does wire breakage. Therefore, if a thin metal wire of particularly small diameter is prepared and its surface is coated with metal by vapor phase method and then processed by cold working; thus, the number of processes can be reduced. Further, processability is good with no excessive force involved in wire drawing, so that efficiency of production is high. As for plastic working subsequent to metal coating by vapor phase method, industrially, wire drawing using a drawing die in the cold is convenient. The use of a drawing die enables plastic working to be performed while enhancing the adhesion between the core and the deposited coating material.

These objects and other objects, features, aspects and advantages of thepresent invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

A BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view of an apparatus for performing coaxial magnetron sputtering method;

Fig. 2 is a schematic view of an apparatus for performing vacuum vapor deposition and wire drawing with a die;

Fig. 3 is a sectional view of a wire obtained according to the invention;

Fig. 4 is a sectional view of a twisted wire conductor using a conductor 101 shown in Fig. 3; and

fig. 5 is a sectional view of a tape-like conductor obtained according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Example 1

Using an apparatus shown in Fig. 1, the surface of a wire of 20 µm in diameter with a clean surface was coated with copper by coaxial magnetron sputtering method to provide a round wire of 30 µm in outer diameter. In Fig. 1, the numeral 1 denotes a core wire; 2 denotes a supply mechanism; 3 denotes a preparatory processing mechanism; 4 denotes a continuous sputtering unit; 5 denotes a magnet; 6 denotes a target; and 7 denotes a winding mechanism.

Said round wire was drawn again using a cold working die to change its diameter to 20 µm. The degree of cold working was 56 %. The wire drawing was smoothly effected with very few wire breaks. The weight per wire break was 5.3 times as much as when drawing a material obtained by a conventional method. Further, according to the method used in this example, the yield was high.

The surface of the wire of 20 µm in diameter formed in the manner described above was coated with copper by sputtering to change its outer diameter to 30 µm, whereupon the wire was drawn to change its diameter 20 µm. The result was the same as described above.

Example 2

Enamel was applied by baking to the surface of the copper wire of 20 µm in diameter obtained in Example 1, whereby the wire was processed into a magnet wire. The magnet wire thus obtained had a good elongation property. That is, whereas the elongation of a magnet wire obtained by a conventional method was 16 %, the magnet wire obtained by the invention exhibited an elongation value of as high as 20 % while having substantially the same strength as said magnet wire obtained by a conventional method.

Example 3

Using an apparatus shown in Fig. 2, an aluminum wire of 100 µm in diameter was produced. In Fig. 2, the numeral 11 denotes a core wire; 12 denotes a supply mechanism; 13 denotes a preparatory processing unit; 14 denotes a die; 16 denotes a driving mechanism; and 17 denotes a winding mechanism.

Concretely, while cleaning the surface of an aluminum wire of 100 µm in diameter having a purity of 99.99 %, aluminum of 99.999 % purity was continuously deposited on said surface by vacuum vapor deposition until the wire diameter was 110 µm. This wire was continuously drawn through a die to reduce its diameter to 100 µm. Thereafter, the wire was subjected to vapor deposition and drawing repetitively, with the same manner, while continuously cleaning its surface. The number of times of vapor deposition and drawing performed was 5; finally, an aluminum wire of 100 µm in diameter was obtained.

The aluminum wire thus obtained was used as a bonding wire for wiring semiconductor elements; the bonding wire was found to exhibit a good corrosion resistance and bonding characteristic.

Example 4

Using the apparatus shown in Fig. 1, the surface of a gold wire of 25 µm in diameter having a purity of 99.99 % was coated with gold of the same purity by sputtering until its outer diameter was 30 µm. The wire thus obtained was drawn to reduce its diameter to 25 µm and was used as a bonding wire.

In this case also, a number of dies can be used for drawing, and it was found suitable to use them in a clean room controlling small-sized auxiliary units attached to the wire drawing machine.

Example 5

After the surface of a copper wire of 0.127 mm in diameter having a purity of 99.95 % was cleaned, the surface of this copper wire was coated with copper of 99.999 % purity until its diameter was 0.16 mm. Thereafter, the wire was drawn until its diameter was 0.127 mm.

A number of thin wires thus obtained were twisted together and insulated. The twisted wire was used for wiring a VTR, and the images and sounds obtained were clear.

Example 6

The surface of a copper wire of 99.99 % purity was coated with copper of 99.999 % by vacuum vapor deposition. The conductor thus obtained was cold-worked using a die so that the percentage reduction in cross-sectional area was 70 %. Fig. 3 shows the cross section of the wire 101 thus obtained. The core 102 is copper of 99.99 %, while the surface area 103 is copper of 99.999 %. The outer diameter is 0.12 mm and the thickness of the coat of high purity copper is 0.01 mm.

To use this conductor 101 for wiring a VTR, 7 such conductors were twisted together to form an electrical wire, as shown in Fig. 4. The sounds and images of the VTR were compared with those obtained by an electrical wire formed of conductors of the same diameter made of a soft material of conventional oxygen-free copper. It was found that when the conductor 101 which is an example of the invention obtained in the manner described above was used, the sounds were very rich and clear and the images were clear.

Example 7

The surface of a copper wire of 99.99 % was coated with copper of 99.999 % by plasma CVD method to provide a tape-like conductor 104 as shown i Fig. 5. the conductor was then punched and used as a lead for transistors in stereos. As compared with a lead of conventional oxygen-free copper, this lead provided clear sounds and sound effects of good quality.

Example 8

The surface of a thin metal wire of 25 µm in a diameter made of Al-1 %Si alloy was coated with aluminum of 99.999 % purity by vacuum vapor deposition to provide a bonding wire of 30 µm in diameter.

In addition, it was very difficult to draw a thin aluminum wire made entirely of 99.999 % Al, which was used as a comparative material, until its diameter was 30 µm. In contrast, it was easy to draw the bonding wire formed in the manner described above.

The bonding wire thus obtained was used for supersonic wedge bonding, and it was found that its bonding characteristic was superior to that of a bonding wire made entirely of Al-1 % Si alloy.

Example 9

The surface of a copper wire of 90 µm in diameter having a purity of 99.99 % was coated with copper of 99.9998 % purity by sputtering until its diameter was 100 µm. It was then drawn until its diameter was 25 µm for use as a bonding wire. This bonding wire was bonded to an Al vapor deposition electrode by ball bonding method making a ball by arc discharge method in an Ar atmosphere. It was found that the wedge bonding area between the bonding wire and the ball bonding area and the wedge bonding area between the bonding wire and an Al-plated lead frame portion were both superior in bonding characteristic.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

Claims

1. A conductor having a core wire whose surface is coated with the same kind of material.

2. A conductor as set forth in claim 1, wherein said coating material is higher in purity than said core wire.

3. A conductor as set forth in claim 1, wherein said conductor is a bonding wire for connecting semiconductor elements.

4. A conductor as set forth in claim 3, wherein said core wire material is copper, aluminum or gold, while said coating material is the same kind of metal higher in purity than said core wire material.

5. A conductor as set forth in claim 4, wherein the purity of said coating metal is 99.999 % or above.

6. A conductor as set forth in claim 1, wherein said conductor is a conductor for use in acoustic and image-forming appliances.

7. A conductor as set forth in claim 6, wherein said core wire is a copper wire of 99.99 % or above purity, while said coating material is copper of 99.999 % or above purity.

8. A method of producing a conductor, comprising the step of coating the surface of a core wire of electrically conductive material with the same kind of material as said core wire material by vapor phase method.

9. A method of producing a conductor as set forth in claim 8, wherein said coating material is higher in purity than said core wire material.

10. A method of producing a conductor as set forth in claim 8, wherein the surface of said core wire is coated with the same kind of material by vapor phase method, and then said core wire is processed until it is a thin wire of predetermined size.

11. A method of producing a conductor as set forth in claim 10, wherein said coating process by vapor phase method and said plastic working process are alternately performed a plurality of times.

12. A method of producing a conductor as set forth in claim 10, wherein the material which forms the surface of said core wire is the same in principal components as said coating metal.

13. A method of producing a conductor as set forth in claim 10, wherein said plastic working is a wire drawing operation using a drawing die.

14. A method of producing a conductor as set forth in claim 10, wherein said plastic working is performed to that the percentage reduction in cross-sectional area is within the range of 15-90 %.

15. A method of producing a conductor as set forth in claim 10, wherein said coating metal is a high purity metal of 99.99 % or above purity.

16. A method of producing a conductor as set forth in claim 10, wherein said core wire and said coating metal are both copper.

17. A method of producing a conductor as set for in claim 10, wherein said core wire and said coating metal are both aluminum.

18. A method of producing a conductor as set forth in claim 10, wherein said core wire and said coating metal are both gold.

19. A method of producing a conductor as set forth in claim 10, wherein said coating by vapor phase method is performed by sputtering.

20. A method of producing a conductor as set forth in claims 10, wherein said coating by vapor phase method is performed by chemical vapor deposition.

21. The product of the method of claim 10.

22. A method of producing a conductor as set forth in claim 8, wherein said conductor is a conductor for use in acoustic and image-forming appliances.

23. A method of producing a conductor as set forth in claim 22, wherein said core wire material is a copper wire of 99.99 % or above purity, while said coating material is copper of 99.999 % or above purity.

24. A method of producing a conductor as set forth in claim 23, wherein said coating by vapor phase method is performed by sputtering.

25. A method of producing a conductor as set forth in claim 23, wherein said coating vapor phase method is performed by chemical vapor deposition.

26. A method of producing a conductor as set forth in claim 23, wherein cold working is performed subsequently to said coating process so that the percentage reduction in cross-sectional area is within the range of 20-90 %.

27. The product of the method of claim 23.

28. A method of producing a conductor as set forth in claim 8, wherein said conductor is a bonding wire for connecting semiconductor elements.

29. A method of producing a conductor as set forth in claim 28, wherein said core wire material is copper, aluminum or gold, and said coating material is the same kind of metal higher in purity than said core wire material.

30. A method of producing a conductor as set forth in claim 28, wherein said coating by vapor phase method is performed by sputtering.

31. A method of producing a conductor as set forth in claim 28, wherein said coating by vapor phase method is performed by chemical deposition.

32. A method of producing a conductor as set forth in claim 28, wherein said coating process is followed by wire drawing.

33. The product of the method of claim 28.

FIG.1

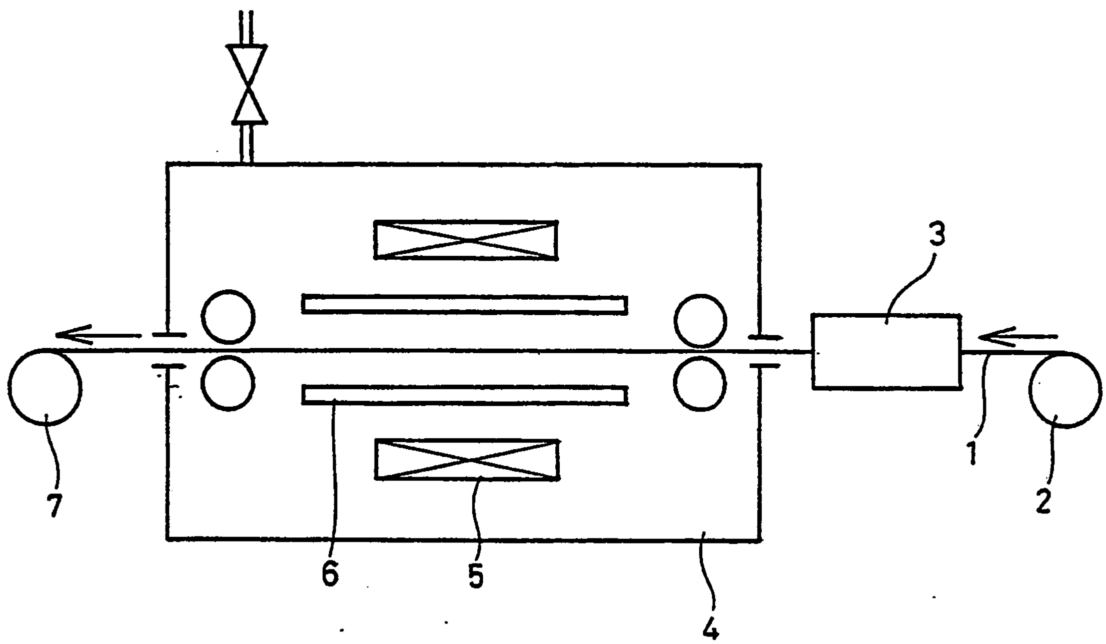


FIG.2

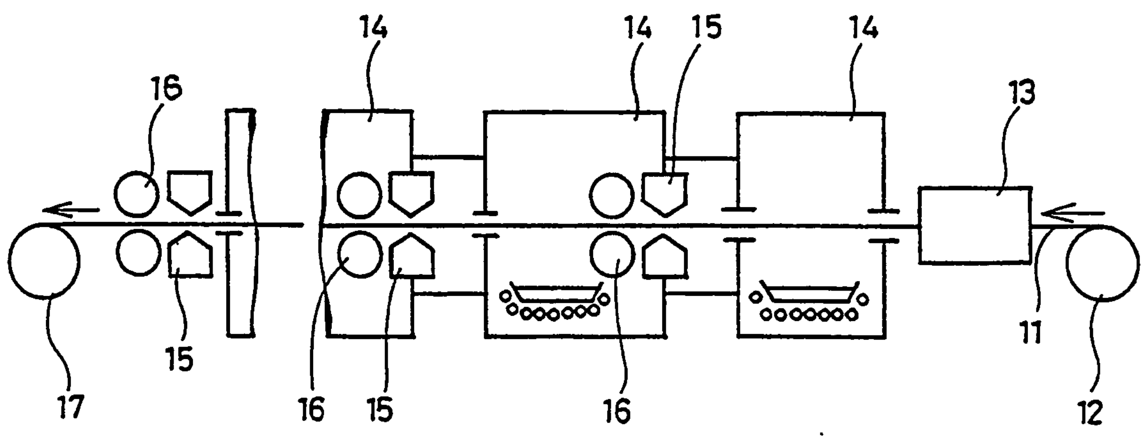


FIG.3

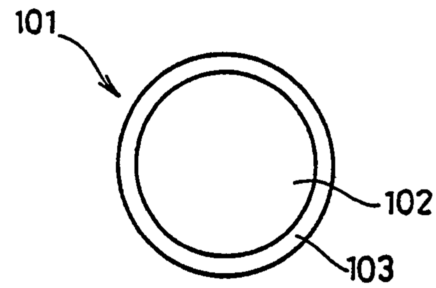


FIG.4

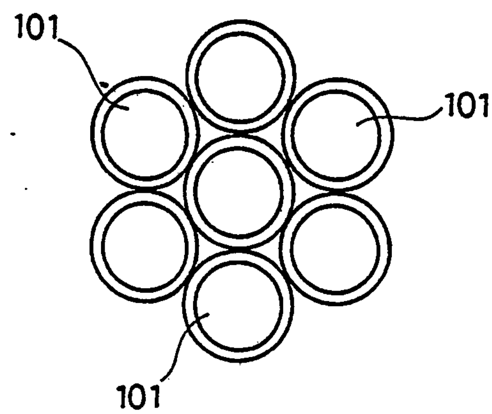
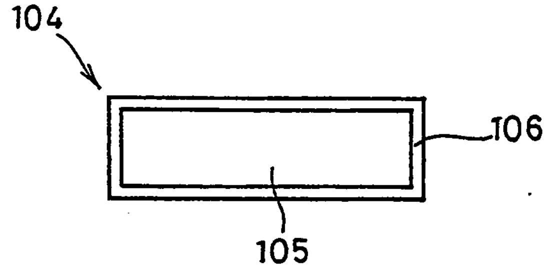


FIG.5



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EUROPEAN SEARCH REPORT

Application number

EP 87 10 3688

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	PATENT ABSTRACTS OF JAPAN, vol. 9, no. 230 (E-343)[1953], 17th September 1985; & JP-A-60 85 546 (TOSHIBA K.K.) 15-05-1985	1-4	H 01 L 23/48 C 23 C 30/00
Y	IDEM ---	8-10, 12,13, 18-21, 28-33	
X	PATENT ABSTRACTS OF JAPAN, vol. 10, no. 168 (E-411)[2224], 14th June 1986; & JP-A-61 18 163 (HITACHI DENSEN K.K.) 27-01-1986	1-4	
Y	IDEM ---	17	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
X	DE-C- 314 791 (L. WEISS) * Claim 1; column 3, lines 10-22 *	1,2	H 01 L C 23 C H 01 B B 21 C
Y	---	8-10, 12,13, 17,18, 20,21, 28-33	
Y	GB-A-1 425 754 (THE ELECTRICITY COUNCIL) * Claim 1 * --- -/-	14,30	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22-07-1987	GREGG N.R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

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EUROPEAN SEARCH REPORT

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EP 87 10 3688

Page 2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	GB-A-1 007 260 (IMPERIAL SMELTING CORP. (IVSC) LTD) * Claims 1-3,10; column 2, lines 76-86 * ---	1,2,6	
A	GB-A-1 489 510 (DELTA ENFIELD CABLES LTD) ---		
A	DE-A-2 937 783 (O. BREITENBACH) -----		

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

The present search report has been drawn up for all claims

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THE HAGUE	22-07-1987	GREGG N.R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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D : document cited in the application
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& : member of the same patent family, corresponding document